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TELEMETRIC STUDIES OF WINTER STEELHEAD,
GOLD RIVER, 1982-83

by

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ABSTRACT

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Studies of the freshwater ethology of wild winter steelhead trout (Salmo gairdneri) were conducted by the Ministry of Environment during the 1982-83 season on Gold River, a major steelhead River in northwestern Vancouver Island. Radio telemetry was employed to monitor in-stream movements and to determine the timing and location of spawning. From December 1982 to April 1983, 219 steelhead were angled a short distance upstream from tidal water; of these, 32 recent immigrants (14.6%) were tagged with internal radio transmitters, and movements monitored approximately weekly. Twenty-four of 32 radio tagged steelhead (75%) were tracked through spawning and emigration. Eight radio tags either malfunctioned, were lost to predation, or were regurgitated.

Of 219 tagged steelhead, 27 (12.3%) were reported recaptured by anglers. Recaptures were highest among steelhead tagged in December and January. Few February tags, and no March-April tags were recovered. Anchor tagged steelhead controls were recaptured nearly three times more frequently than radio tagged fish. Reduced catchability resulting from orally inserted transmitters with external antennae is implied. Telemetric observations also suggested that fish behavior may have been modified in the short term by internal transmitters.

Telemetric monitoring showed that early steelhead immigrants (December, January) occupied heavily fished areas of Gold River for three to four months prior to spawning, and recapture data confirmed the vulnerability of these fish to angling.

The relationship, if any, between stream temperature and discharge and the rate of upstream migration of tagged fish was not determined. However, substantial upstream movements were observed during periods of low and declining discharge. Steelhead spawning was randomly distributed throughout approximately 30 km of the mainstem. December and January immigrants spawned three to seven weeks earlier than February through April immigrants. Post-spawning emigration was rapid among both sexes.

Implications of study results to management of wild winter steelhead on Vancouver Island are discussed.

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INTRODUCTION

Vancouver Island steelhead streams are characteristically short, relatively small, and readily accessible to anglers throughout most of their length. Winter steelhead (Salmo gairdneri) enter these streams between November and May and often reside for several months before spawning. Extended freshwater residence, the physical nature of the streams, and intense angling pressure precipitated general declines in annual catches, suggesting that restrictive regulations were required to prevent overexploitation of wild winter steelhead stocks. In addition, creel survey data (MOE unpubl. data) showed that early winter steelhead stocks (i.e., December to February) were harvested disproportionately by anglers. Fish which immigrated in early winter were assumed to spawn earlier than their March/April counterparts; there was further speculation that their eggs experienced lower survival through exposure to more severe incubation conditions (lower water temperature, higher stream discharge, greater frequency of freshets). For these reasons, wild winter steelhead harvest was reduced in 1981 to two fish/month and a maximum aggregate of five/year during November, March and April. Catch and release was in effect from December to February.

These regulatory changes were considered necessary to reverse observed declines in catches of wild winter steelhead. Once implemented, a process of evaluating their efficacy was required; radio telemetry provided the means to pursue this goal. Equipment and techniques have developed rapidly during the past decade (Solomon 1982; Minor 1981; Stasko and Pincock 1977), and a number of investigators have successfully employed telemetric methodologies to examine various aspects of steelhead ethology and ecology (Pettit and Lindland 1979; Spence 1980, 1981; Lough 1980, 1981; Witt *et al.* 1980; Burger *et al.* 1983; Wallis and Balland 1984). Gold River, the leading wild winter steelhead producer on Vancouver Island, was selected as a typical site to initiate telemetric studies.

Study objectives were to:

1. Examine the in-stream movement of winter steelhead in relation to timing of immigration into the river.
2. Assess the relative vulnerability of early (December/January) versus late (March/April) immigrant winter steelhead to angling.
3. Determine the spatial and temporal distribution of tagged steelhead spawners.
4. Examine the post-tagging behavior and survival of tagged winter steelhead.

5. Assess the efficacy of estimating winter steelhead stock sizes using the mark and recapture technique.

DESCRIPTION OF THE STUDY AREA

Located on northwestern Vancouver Island, Gold River originates in the Sutton Mountain Range and flows 50 km south-southwest to discharge into Muchalat Inlet (Fig. 1). Gold River is comprised of numerous tributaries and small lakes which drain an area of 1010 km². Only two tributary systems are accessible and utilized by steelhead and, of these, only one (Muchalat River) is frequented by winter steelhead.

The Gold River hydrograph is typical of coastal streams of British Columbia. Highest mean monthly flows occur from October to May, and discharge from winter freshets usually exceeds spring snow runoff. Mean annual discharge is 84.7 m³/sec, and extremes have ranged from 3.6 (August) to 1890 m³/sec (November) (Water Survey Canada 1983). Mean annual precipitation is 3741 mm (Atmospheric Environment Service 1971), and is greatest during November through January. The Gold River flow regime is extremely responsive to rainfall, and rapid fluctuations in discharge occur frequently.

Significant escapements of sockeye (Oncorhynchus nerka), chinook (O. tshawytscha), coho (O. kisutch) and chum (O. keta) salmon and remnant even-year pink salmon (O. gorbuscha) occur in Gold River (Brown et al. 1979). Both summer and winter steelhead are present in the drainage. Winter steelhead dominate and form the basis of a relatively intense sport fishery from December through April. The fishery occurs from tidewater (km.2) to the sport fishing boundary (km.24) but is concentrated between river km.4 and 10 (Fig. 1). During the fishing seasons which ended in the winters of 1982-1984, anglers averaged 3,912 days fished and 6,093 steelhead caught annually (Billings 1982, 1983, 1984). Gold River is designated as a "wild trout stream" and hatchery-produced steelhead are absent.

Logging occurs throughout the drainage. Road development along the principal watercourses is extensive, thus facilitating ready access for monitoring tagged fish locations. The area population is approximately 3,000, most of whom are associated with logging or wood processing facilities in the town of Gold River.

METHODS

Wild winter steelhead were captured by project staff using conventional angling gear. Fish were angled in the lower reaches of Gold River 0.2 - 5.0 km upstream of tidal influence between December 1982 and April 1983 (Fig. 1). All fish landed were marked with two colored and numbered anchor tags (length 5 cm) inserted in the dorsal musculature on opposite sides of the dorsal fin between the anterior pterygiophores. Steelhead

selected for radio tagging were marked with bright orange tags, while non-radio tagged (control) fish received yellow tags.

Radio tags were applied in sets at approximately one month intervals commencing the first week of December. The target was to tag three males and three females during each radio tagging period. Only fish judged to be completely healthy (no wounds or angling-related injury) and recent immigrants (e.g., 0-5 days) from the marine environment were selected for radio tagging. All other steelhead received only anchor tags. Criteria used to assess timing of immigration included coloration ('brightness') and the presence of sea lice (Lepeophtheirus salmonus). Each monthly tag set was considered a separate group for monitoring and analysis.

Radio tags used in the study were Wildlife Materials model HLPI-2120 miniature 2-stage transmitters encased in dental acrylic from which a 28 cm (0.31 mm diameter) stainless steel whip antenna protruded. Transmitters were individually identifiable and operated on frequencies which ranged from 150.938 to 151.398 MHz. Each was powered by a 2.8 v, 1.2 ah lithium battery with a guaranteed life of 200 days. The tag was 6.0 cm in length, 2.4 cm in diameter and weighed approximately 30 g, well within the recommended range ($\pm 2\%$ of fish body weight; Stasko and Pincock 1977) for fish of the minimum size expected.

Transmitters were inserted orally into the stomach, posterior to the pneumatic duct, with a hollow fiberglass tube (1 cm x 25 cm) in which the antenna was sheathed. Upon removal of the tube, the antenna which trailed from the mouth was drawn out from behind the left posterior gill arch through the opercular cavity using a crochet needle, and positioned along the left flank (adapted from McCleave *et al.* 1978). Anaesthetic was not required as fish were docile after capture. Radio tagged and control steelhead were released at the capture location immediately after tag application. Sex and anecdotal data (i.e., presence of sea lice, wounds, scars, coloration) were recorded and weight was estimated subjectively.

Movements of radio tagged steelhead were monitored approximately weekly using a Telonics model TR-2 receiver operating between frequencies of 150.000 and 152.000 MHz and equipped with a Telonics model TS-1 scanner/programmer. The receiving unit was housed in a Sexton Photographics model 9120 waterproof Plexiglas case. Radio tagged steelhead were located from vehicle, helicopter and boat. For vehicle and boat scanning, a Telonics model RA-2AK 2-element beam antenna was used; during aerial tracking, a Telonics model RA-3, 3-element yagi beam antenna was employed. The receiver and antennae were used with low impedance Telonics model RH-1 headphones. During monitoring reconnaissance, the precise location (± 50 m) of each radio tag detected was recorded on large scale maps of the Gold River drainage. Radio tag locations were recorded as weekly data

sets with the December 1-7 interval as week 1 and the April 24-30 interval as week 25. Spawning was assumed to have occurred at the last detected upstream location which was followed by sustained downstream movement.

Angler cooperation in reporting the movements of tagged fish was solicited by posting notices at angling accesses and in public buildings in the town of Gold River. In addition, the program was advertised in local media. Anglers capturing a tagged steelhead were requested to record the date, location, and tag numbers, then release the fish, and report these data to any Fish and Wildlife Branch office.

Snorkel surveys were conducted by paired observers during favorable water conditions to enumerate steelhead, determine tag:untagged ratios, confirm the fate of radio tags which had remained stationary for extended periods, and collect anecdotal observations.

Daily water temperatures were recorded by a calibrated Peabody Ryan model J thermograph located in the Tahsis Company pulp mill water intake facility immediately adjacent to the river (Fig. 1). Stream discharge data for the study period were acquired from Water Survey of Canada Station 08HC001 located downstream from the Ucona River confluence (Fig. 1).

RESULTS AND DISCUSSION

TAG DISBURSEMENTS

From December 1982 to April 1983, 219 steelhead were angled, tagged, and released; of these, 32 (14.6% were radio tagged. Tagging dates, locations, sex ratios and estimated weights of control and radio tagged steelhead are summarized in Tables 1 and 2, respectively. Among the angled population, females predominated slightly (116:103; F:M 1.3:1). The average size of steelhead tagged was generally largest from December through mid-January, although large fish were angled in February and March. Size variation among radio tagged steelhead was less than in the control group, as we endeavored to minimize the risk of injury to smaller fish (i.e., < 2.8 kg), and the risk of tag regurgitation by larger steelhead (i.e., > 7.0 kg).

TRANSMITTER VIABILITY AND RETENTION

Of 32 steelhead with radio transmitters implanted, 24 (75%) were monitored through spawning and emigration. Two radio tags could not be located after the first several hours following release and were assumed to have malfunctioned. One other tag produced weak and/or intermittent signals for three weeks before detection became impossible. A fourth tag apparently functioned but interference with the signal was pronounced and recorded locations were too infrequent to be of value.

Table 1. Temporal and spatial disbursement of anchor tags in Gold River steelhead, December 1982 - April 1983.

Date	Year	Number Tagged		Mean Estimated Weight (kg)				River km Released	
		M	F	Males	Range	Females	Range	Mean	Range
06/12	1982	1	0	5.9	-	-	-	4.25	-
07/12		1	4	2.7	-	5.1	3.6-6.4	5.13	1.35-5.85
15/12		2	2	3.9	3.2-4.5	6.1	5.9-6.4	4.38	4.25-4.75
21/12		4	5	6.1	4.6-9.1	4.8	2.1-7.5	6.75	5.20-9.60
30/12		5	3	5.7	3.2-7.3	4.5	2.7-5.9	5.19	3.90-5.75
Subtotal		13	14	4.9	3.2-9.1	5.1	2.1-7.5	5.14	1.35-9.60
05/01	1983	8	8	4.4	2.7-5.7	4.3	2.7-5.9	6.07	4.50-6.30
06/01		1	1	2.3	-	4.5	-	8.90	-
12/01		3	1	3.2	2.7-3.6	5.0	-	3.88	2.00-4.50
20/01		13	10	3.6	2.7-5.9	3.8	2.7-5.5	5.28	4.25-5.85
26/01		2	3	3.0	2.7-3.2	4.2	3.2-5.5	5.06	4.50-5.35
27/01		5	8	3.4	3.2-3.6	3.4	2.7-4.5	5.65	3.55-5.90
29/01		6	6	3.4	1.8-4.5	3.3	1.8-5.5	5.47	4.25-6.30
Subtotal		38	37	3.3	1.8-5.7	4.0	1.8-5.9	5.76	2.00-6.30
02/02		2	2	4.5	3.6-5.5	4.5	3.6-4.5	5.41	3.80-6.30
14/02		6	7	4.3	2.7-5.9	4.3	2.7-5.9	3.67	1.80-5.60
15/02		6	7	5.7	2.7-8.2	4.7	2.7-5.9	3.33	2.00-5.90
23/02		13	11	3.6	2.7-4.5	3.0	2.3-6.8	3.23	1.40-4.50
Subtotal		27	27	4.5	2.7-8.2	4.1	2.3-6.8	3.91	1.40-6.30
01/03		2	2	3.6	2.7-4.5	2.7	-	5.23	4.75-6.30
02/03		1	3	3.2	-	3.3	2.7-4.5	5.80	5.60-6.30
10/03		6	13	3.9	2.3-5.5	4.7	3.2-7.7	3.02	1.80-5.60
22/03		1	0	2.3	-	-	-	4.75	-
28/03		0	2	-	-	2.7	2.3-3.2	5.28	4.25-6.30
Subtotal		10	20	3.3	2.3-5.5	3.4	2.3-7.7	4.82	1.80-6.30
07/04		0	1	-	-	2.3	-	6.30	-
Subtotal		0	1						
Total		88	99	3.9	1.8-9.1	4.1	1.8-7.7	5.09	1.35-9.60

Table 2. Temporal and spatial disbursement of radio transmitters in Gold River steelhead, December 1982 - April 1983.

Tagging Date	Tag Group	Sex	Estimated Weight (kg)	River km Released	Transmitter Frequency (mHz)	Fish No.	Fate
02/12	Dec	M	3.6	4.25	151.112	1	TTE
06/12		F	5.0	5.25	151.162	2	TTE
06/12		F	5.5	5.90	151.102	3	TTE
06/12		M	3.6	5.85	151.023	4	TTE
06/12		M	8.2	5.85	150.938	5	TTE
06/12		F	6.4	5.25	151.059	6	TTE
06/12		M	3.6	5.20	151.041	7	TTE
30/12	Jan	M	4.1	5.40	150.956	8	TTE
30/12		M	3.2	5.45	151.032	9	TTE
30/12		F	3.2	3.80	151.089	10	TTE
05/01		F	5.5	5.40	150.911	11	TTE
05/01		F	3.2	5.60	151.074	12	TTE
05/01		F	5.5	6.30	151.260	13	DIS
05/01		F	5.7	6.30	151.030	14	TTE
05/01		M	5.7	5.45	151.290	15	REG
27/01	Feb	F	3.6	5.35	151.237	16	TTE
27/01		F	3.2	4.50	151.362	17	TTE
30/01		F	3.2	5.60	151.310	18	TTE
02/02		F	5.9	5.35	151.398	19	TTE
02/02		M	3.2	5.35	151.337	20	TTE
02/02		M	3.6	4.25	150.962	21	INT
23/02	Mar	M	3.2	2.50	151.084	22	TTE
23/02		M	3.2	2.50	151.103	23	DIS
24/02		F	6.4	4.50	151.113	24	TTE
23/02		F	7.3	3.60	151.023	25	TTE
23/02		F	3.4	1.40	151.071	26	REG
02/03		F	2.7	4.75	151.239	27	TTE
02/03	Apr	M	2.7	5.60	151.261	28	PRE
28/03		F	3.6	6.30	151.290	29	REG
29/03		F	3.6	6.30	150.937	30	TTE
07/04		F	5.5	6.30	151.162	31	TTE
08/04		M	3.7	6.30	151.057	32	MAL

TTE - tracked to emigration

REG - tag regurgitated

PRE - tagged fish predated

DIS - tagged fish disappeared

INT - interference with transmitter

MAL - transmitter malfunction

Transmitter failure is a predictable and expected occurrence in aquatic telemetric investigations involving anadromous salmonids. Incidence of tag malfunction in the present study (3/32 or 9.4%) was within the reported range for similar investigations. Haynes and Gray (1981) found 4.7% (3/64) failures among Snake River chinook. Spence (1980) experienced 33% (9/27) failure in an initial investigation of Chilcotin River summer steelhead, but only 5.7% (2/35) during the following year (Spence 1981). Cleugh and Russell (1980) reported 12.5% (3/24) failures in studies of Yukon River chinook, Pettit and Lindland (1979) 7.1% (1/14) with Clearwater summer steelhead, and McCleave et al. (1978) 7.5% (3/40) during research with Atlantic salmon (S. salar) in the Penobscot River. Other investigators report inability to detect radio signals after fish liberation, but fail to isolate causes (i.e., Witt et al. 1980; Brawn 1982; Wallis and Balland 1984).

Three (9.4%) radio tagged steelhead regurgitated tags within two, five and seven weeks, respectively, of tagging. The phenomenon of tag regurgitation was also not unexpected. Brawn (1982) experienced 15.8% (3/19) rejection and McCleave et al. (1978) 12.5% (5/40) among adult Atlantic salmon. Spence (1981) observed 14.3% (5/35) tag loss and Pettit and Lindland (1979) 8.3% (1/12) among summer steelhead. Tag regurgitations did not appear to be related to size of steelhead in the present study (Table 2). All regurgitated tags were recovered intact by project staff.

A predator apparently captured one radio tagged steelhead approximately six weeks following liberation. Both radio and anchor tags were recovered from the river bank; the fish had remained stationary for several weeks following a period of relatively rapid upstream movement.

RECAPTURE RATES OF TAGGED STEELHEAD

During the 1982-83 season, Gold River anglers recorded and returned data for 27 tagged steelhead (Appendix I). This represented 12.3% of 219 steelhead at large. Two of 27 (7.4%) were recaptured a second time. Tag numbers from seven additional control steelhead were not recorded by anglers, but it was probable that these represented first recaptures. Only 6.3% (2/32) of radio tagged steelhead were recaptured while 17.1% (27-2+7/187) of control fish were caught a second time.

The difference between recapture rates of radio tagged and control steelhead was likely related to reduced catchability of the former. Other telemetric studies of steelhead and chinook involving orally implanted transmitters with external antennae have shown similar findings. Spence (1980) reported 7.4% (2/27) angling recapture of radio tagged steelhead and 13.6% (3/22) recaptures of control fish. A similar investigation conducted the following year (Spence 1981) reported 5.7% (2/35) c.f. 15.8% (12/76) recapture for radio tagged and control fish,

respectively. Haynes and Gray (1981) compared the effect of internal and external tags on chinook salmon and reported 7.7% (3/39) angling recaptures among externally tagged fish but 0.0% (0/25) recovery of those tagged internally.

Reported angling recapture rates in studies involving steelhead bearing internal transmitters and internal loop antennae, or surgically implanted transmitters (with internal or external antennae) suggest that the antenna protruding from the oral or opercular cavities is the factor responsible for reducing catchability. Lough (1980) noted 19% (4/21) recaptures among two stocks of summer steelhead and 13.6% (11/81) among several other stocks in a subsequent study (Lough 1981). Pettit and Lindland (1979) found a minimum angling recapture of 30.8% (4/13) among summer steelhead bearing internal transmitters and loop antennae. Wallis and Balland (1984) observed similar angling recapture rates between anchor tagged steelhead (22/133 or 16.5%) and those bearing surgically implanted transmitters (3/16 or 18.7%).

The frequency of tag recaptures among steelhead tagged in a given month declined progressively over the study period. Almost 30% of tags applied in December were reported recaptured while none of the steelhead tagged in either March or April were recaptured (Table 3). Only two fish were reported recaptured a second time and both of these were tagged in December. These results support the assumption that fish which immigrate earliest (i.e., December/January) were significantly more likely to be caught one or more times than their later immigrating (i.e., March/April) counterparts ($p < 0.01$). The average period between tagging and first recapture was 31 days (standard deviation = 27, range = 1-80), but approximately half occurred either in < five days ($n = 7$) or > 50 days ($n = 7$).

Table 3. Reported angling recaptures of anchor and radio tagged steelhead by month of tag application, Gold River, December 1982 - April 1983.

<u>Month Tagged</u>	<u>Population at Large</u>	<u>Number Recaptured¹</u>	<u>(%)</u>
December	37	11	(29.7)
January	83	15	(18.1)
February	62	3	(4.8)
March	34	0	(0.0)
April	3	0	(0.0)

¹Includes both first ($n = 27$) and second ($n = 2$) recaptures.

MIGRATION OF TAGGED STEELHEAD

Movements of radio tagged steelhead were analyzed both individually and by tag group (Fig. 2; Appendix 2). A notable feature of the post-tagging location of the majority of tagged fish was that they remained static or moved slightly downstream, often for lengthy periods. Other related investigations showed similar tendencies (Spence 1980; Monan and Liscom 1972; Cleugh and Russell 1980; Pettit and Lindland 1979; Burger *et al.* 1983, Burger *et al.* 1985), but such observations are not necessarily consistent (e.g., Solomon 1982; Burger *et al.* 1981; Wallis and Balland 1984). Whether or not such behavior would have occurred in the absence of capture, handling and transmitter insertion could not be determined by the present investigation. However, comparisons of recapture locations for control steelhead (Fig. 3) suggest that radio tags delayed upstream migration. Only four of 15 (27%) control recaptures which occurred in the month after tagging were at or downstream from the original tagging site (Appendix 1). However, 15 of 24 (63%) radio tagged fish remained stationary or moved downstream from the tagging site in the month after tagging (Appendix 2). Two of the four control recaptures occurred at the same location, one and four days, respectively, after tagging. All control steelhead tagged in December (the only month of the investigation with reasonable assurance that all fish tagged were recent immigrants) and later recaptured were taken upstream from the initial capture site (Fig. 3). December control steelhead which were recaptured represented a minority of the control population, however, and it was possible that recapture data were biased toward fish which moved upstream because they were less affected (or 'healthier') following capture and tagging. Published data on the behavioral influence of attaching telemetry transmitters were insufficient to support conclusions based on these observations (Mellas and Haynes 1985).

Migration rates and point locations of radio tagged steelhead within and between tag groups varied markedly. This was possibly a reflection of ethological influences alluded to previously, a random distribution of spawners throughout the available habitat irrespective of timing of immigration (i.e., homing), or some interactive combination of these. Tag location data treated individually were not instructive. However, averaging the location of all tagged fish in a monthly group did provide a basis upon which comparisons could be made. This procedure illustrated that fish entering Gold River earliest ascend slowest and are resident in popular fishing areas longest (Fig. 2, Table 4). Considering the relative length of accessible reaches of Gold River and the immature condition in which winter steelhead enter the river, the observed migration rates were not unexpected. Average pre-spawning stream residence for December, January, February, March and April tag groups was 119, 91, 84, 56, and 35 days, respectively. Average residence in the heavily fished area between river km.4 and 10 was 70, 56, 42, 35, and 35 days for December, January, February, March, and April tags, respectively. These data again confirm that early immigrants are

continuously available and vulnerable to anglers during the peak fishing period (mid-December to early March). Spence (1980, 1981), Lough (1980) and Solomon (1982) reported similar observations.

Table 4. Mean location and rate of upstream migration of radio tagged Gold River steelhead of various monthly tag groups during the 1983 migration period.

Tag Group	Sample Size	Mean Location Feb 15 (km)	Mean Location Apr 01 (km)	Mean Upstream ¹ Migration Rate ¹ (km/week)
December	5	12.4	14.4	0.6
January	6	10.1	14.7	0.8
February	5	5.0	11.6	1.1
March	5	n/a	8.6	2.5
April	3	n/a	6.3	2.0

¹Calculated as the rate of upstream movement between tagging and the first week in which the net movement among all steelhead in a given monthly group was downstream.

In the absence of periods of continuous telemetric monitoring during the present investigation, it was impossible to determine maximum upstream migration rates or the influence of rapid fluctuation in discharge. Observations based on weekly reconnaissance showed maximum upstream movements of 14-15 km/week among three male steelhead (no. 7, 20 and 28; Appendix 2). These movements occurred during weeks 4, 17 and 16, respectively, all of which were characterized by low and declining discharge (Fig. 4). These data contrasted with published information on another temperate stream of moderate size which indicated that major mid-season movements occurred on high and rising flows (Pettit and Lindland 1979).

Tracking observations during a peak discharge event in the first week of December (Fig. 4) showed that tagged fish moved laterally to the stream margin where velocities were least. Similar movements or downstream displacement were noted by Lough (1980), Winter (1976), and Monan and Liscom (1971).

The influence of water temperature on migration behavior was not resolved by the present study. However, several radio tagged steelhead showed sustained ascent during weeks 15 to 20 (Appendix 2) when daily water temperature first exceeded 5°C (Fig. 5). Pettit and Lindland (1979) and Burger *et al.* (1983) also reported significant upstream movements of radio tagged steelhead during late winter as water temperatures increased.

SPAWNING LOCATION, TIMING AND EMIGRATION

Analyses of the spatial distribution of radio tagged steelhead spawners did not show any distinct pattern. Tagged adults spawned relatively uniformly over 29 km of Gold River mainstem (Fig. 6), and the distribution of fish from different monthly tag groups was equally scattered. These observations suggest that tagged steelhead originated from throughout the mainstem habitat and homed to the rearing area as returning adults.

Mean spawning time, as determined by the week of maximum upstream location, followed by sustained downstream migration, was earliest for the December radio tagged steelhead, and was generally progressively later for tag groups which followed (Table 5). A temporal partition of 3 to 7 weeks in mean spawning time was evident between females from the December and January components and their February through April counterparts. Males of a given tag group lingered in spawning areas for up to 4.3 weeks after females with which they immigrated had commenced emigration (Table 5). Delayed emigration among males was, presumably, related to promiscuity and has been observed elsewhere (Spence 1980, 1981; Everest 1973; Winter 1976).

Table 5. Mean week of emigration commencement and differences between sexes of radio tagged Gold River steelhead of various tag groups, 1983.

Tag Group	Mean Emigration Commencement Week		
	Females	Males	Difference (weeks)
December	16.0 (1)	20.3 (3)	4.3
January	17.5 (4)	21.0 (2)	3.5
February	20.3 (4)	24.0 (1)	3.7
March	21.5 (2)	21.5 (2)	0.0
April	23.3 (3)	- (0)	-

() Sample size

Emigration of radio tagged post-spawners was relatively rapid, irrespective of tag group and sex (Appendix 2). Once emigration began, radio tags were often undetectable the following week, thus indicating steelhead had left the watercourse. Actual rates of emigration could not be calculated because the precise dates of initiation of downstream migration and river exit were not determined. Spence (1980) and Burger *et al.* (1983) reported similar difficulties.

POPULATION ESTIMATION

During snorkel observations adult steelhead were frequently encountered in groups of 50 or more milling around and presenting little opportunity to do more than estimate numbers. Anchor tags were generally impossible to observe even though the location of many radio tagged steelhead was known in advance and snorkelers were searching specifically for them. Longer anchor tags or an alternate tag type probably would not have altered these results.

Snorkel surveys provided useful data on the relative abundance and distribution of adult steelhead. However, given the limitations of water clarity, even during the most favorable conditions available in Gold River in winter, the detectability of tagged fish was less than adequate to determine marked:unmarked ratios and to estimate the population by a mark and recapture formula. In addition, assumptions implicit in the methodology (i.e., no immigration or emigration, tagged fish distribution reflects population distribution, complete tag retention and detection, equal catchability of tagged and untagged steelhead) were often violated. Also, the numbers of fish which was tagged was small relative to the expected population and, even if the inherent assumptions were met, too few marks were available for observation (recapture) to be of value.

MANAGEMENT IMPLICATIONS

1. Data collected during the Gold River radio telemetry project confirmed that winter steelhead, particularly those entering the river earliest, occupied intensively fished areas for extended period prior to spawning. These data are likely typical of other Vancouver Island steelhead streams, many of which are smaller, shorter, and more accessible for angling than Gold River. Hence, the vulnerability of early winter steelhead and the need for conservative harvest regulations is supported. As angler awareness and expertise broaden, leisure time increases, gear efficiency improves, and access expands (power and drift boats), the proportion of the total steelhead run caught and the frequency of repeat captures will continue to increase. These circumstances, together with small stock sizes and present regulations which are inadequate to control stock-specific harvest in the presence of a kill fishery, demand that no-kill regulations be maintained during the earlier winter months.
2. Radio telemetry is a powerful technique which can be used to advantage in a broad array of fisheries investigations. In British Columbia, the application of the technique in studies involving steelhead migration has been relatively extensive. The behavioral influences of fish handling and tagging, however, are neither well documented nor understood. Tag "disappearances" and significant post-tagging downstream

movements were common among these and numerous other literature sources. These and the present study imply that caution must be exercised when developing inferences on important management issues. Results on run timing, migration rates, harvest rates, recapture frequencies, and spawning distribution could be misleading when such conclusions are based on small samples and a single year of investigation (i.e., ignoring annual variability). Further research into the behavioral impacts of some radio tagging procedures and equipment is warranted.

3. Population estimation using conventional mark and recapture techniques is inappropriate for Vancouver Island adult steelhead stocks unless opportunities exist to mark and observe (recapture) substantial numbers of fish. In the absence of such opportunities, direct observation by snorkeling should provide relative counts. Care must be exercised, however, to select representative times and streams (reaches).
4. Experience in this and other investigations has demonstrated that anglers often fail to report (or report incompletely) marked fish captures, despite the fact that their level of awareness of project objectives was high. Management studies incorporating data provided voluntarily by anglers should be designed such that information via this source is not exclusive or critical.

SUMMARY

1. During the 1982-83 winter steelhead season, the MOE undertook a radio telemetry program in Gold River, Vancouver Island's most prolific steelhead stream. The study was designed to examine the timing of river entry relative to migration behavior and the temporal and spatial distribution of spawners. Results were intended for use in evaluating recently imposed regulations restricting wild steelhead harvest.
2. Between December 1982 and April 1983 project staff angled, tagged, and released 219 steelhead of which 32 (14.6%) were radio tagged.
3. Twenty-four of 32 (75%) radio tagged steelhead provided complete data records through spawning and emigration. Of the remaining eight tags, three malfunctioned, three were regurgitated, one was obscured by interference, and one was predated. These results were within the published range for tag retention and viability among adult anadromous salmonids.
4. Of 219 tagged steelhead at large, 27 (12.3%) were reported recaptured by anglers. Recaptures were highest among December steelhead (29.7%) and declined progressively through

January and February. No steelhead tagged in March or April were recaptured. Control group steelhead were recaptured approximately three times more frequently than radio tagged fish. Data inferred that orally implanted tags with external antennae served to reduce the catchability of radio tagged steelhead.

5. Radio tagged steelhead commonly remained at the tagging location or moved downstream immediately following liberation. Control group recapture data implied that radio tag insertion may have interrupted normal upstream migration.
6. Analyses of average location of monthly radio tag sets indicated that fish which entered the river earliest occupied popular, heavily fished areas for periods of three to four months prior to spawning. Vulnerability to capture was assumed to be directly related to the duration of freshwater residence (i.e., time of river entry).
7. The influence of stream discharge and water temperature on tagged steelhead movements was not determined. However, limited data suggested that major mid-season movements occurred on low and declining discharge. Significant movements appeared to be related to water temperatures exceeding 5° C.
8. Spawners of a particular monthly radio tag group spawned at locations distributed randomly throughout the available habitat, possibly reflecting homing behavior. December and January females spawned three to seven weeks earlier than their February through April counterparts. Males lingered in spawning areas for up to 4.3 weeks after females of similar river entry timing had emigrated. Emigration, once initiated, was rapid among both sexes and all radio tag groups.
9. Population estimates from mark and recapture data collected by angling and by snorkel observation were negated by inadequate sample sizes and/or the detectability of tagged fish. The preferred method of estimating stock size was direct enumeration via snorkeling.
10. Results of the telemetry program confirmed the vulnerability of steelhead to angling in a typical Vancouver Island stream. Given observed trends in the sport fishery, restrictive regulations designed to protect early winter steelhead and restore depleted stocks should be maintained.

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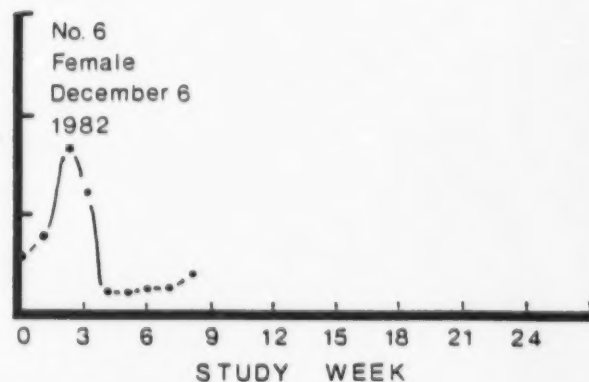
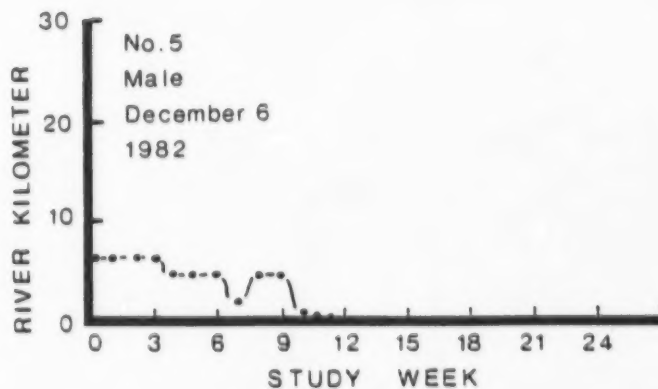
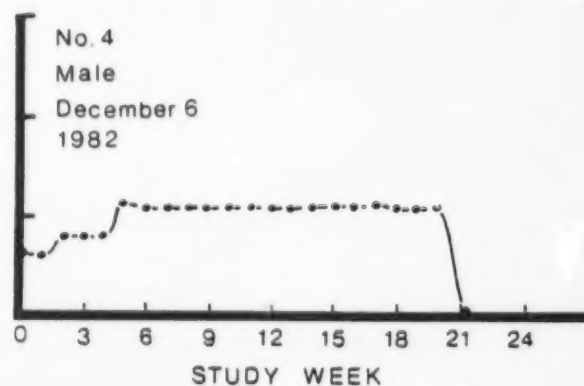
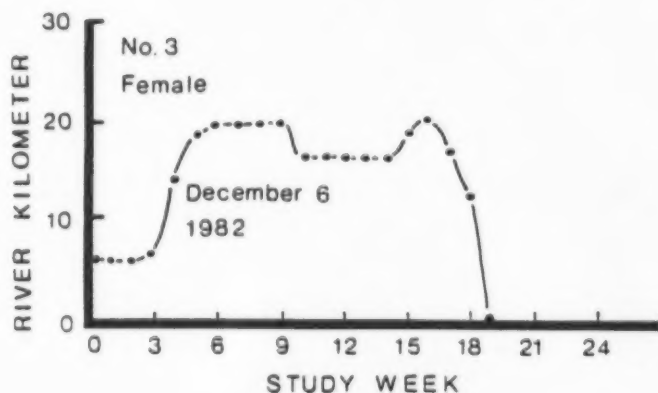
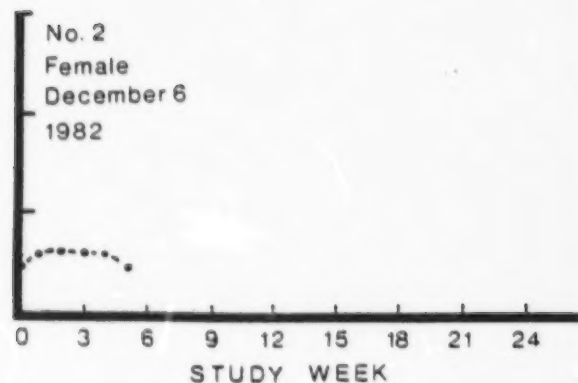
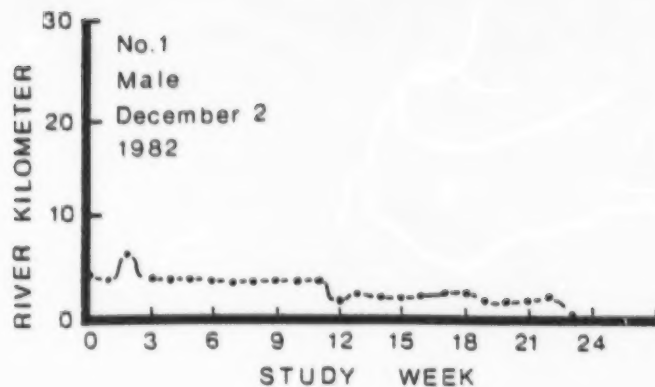
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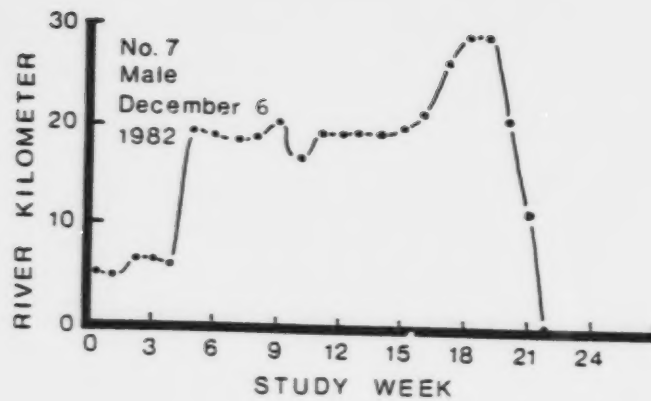
Appendix 1. Timing and locations of recaptures of tagged steelhead, Gold River, 1982/83.

<u>Date Tagged</u>	<u>1st Recapture Date</u>	<u>Location</u>	<u>Net Movement (km)</u>	<u>2nd Recapture Date</u>	<u>Location</u>	<u>Net Since Tagging</u>	<u>Movement (km) Since 1^o Recapture</u>
07/12	09/12	5.90	+1.15	13/02	11.5	+6.7	+5.6
07/12	15/12	8.85	+3.00				
30/12	#10 02/01	4.75	+1.05				
12/01	15/01	3.80	+1.80				
21/12	14/01	5.90	+0.65				
30/12	14/01	5.90	+0.15				
29/01	30/01	5.60	0.00				
26/01	31/01	4.75	-0.25				
30/12	26/01	14.20	+8.85				
02/02	14/02	18.60	+12.30				
27/01	15/02	10.80	+6.30				
07/12	23/02	2.00	+0.65	15/03	2.2	+0.2	+0.85
20/01	23/02	4.50	-1.20				
29/01	26/02	5.60	-0.70				
07/12	25/02	9.60	+4.85				
15/02	19/02	5.80	0.00				
30/12	18/02	5.90	+0.30				
29/01	18/02	9.60	+4.00				
05/01	18/02	5.90	-0.04				
20/01	01/03	9.75	+5.50				
15/02	05/03	3.80	+1.80				
05/01	22/02	22.80	+16.50				
05/01	#14 23/03	18.25	+11.95				
05/01	12/03	10.80	+5.30				
20/01	16/03	18.60	+14.10				
15/01	15/03	2.20	-0.30				
06/01	26/03	11.50	+2.60				

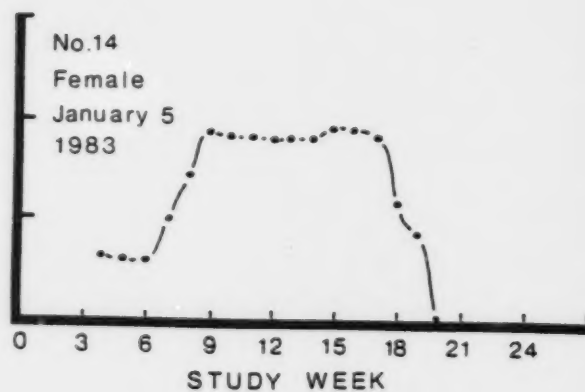
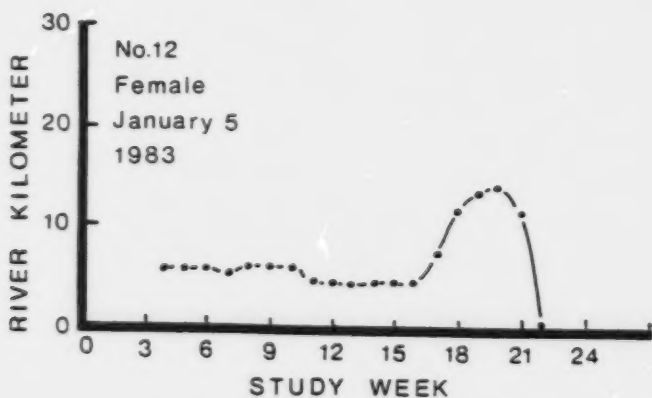
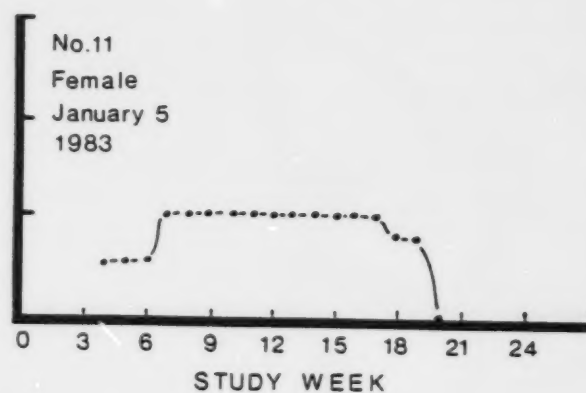
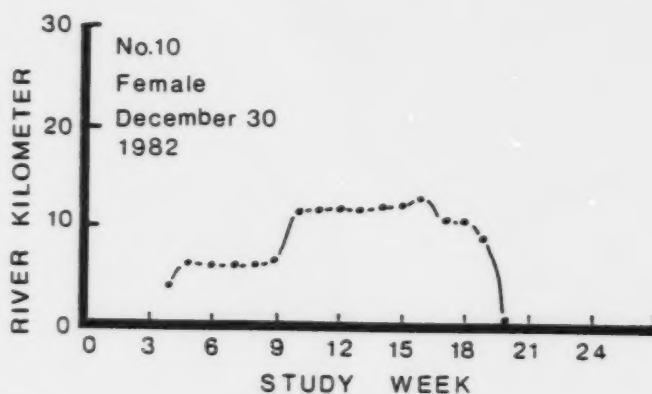
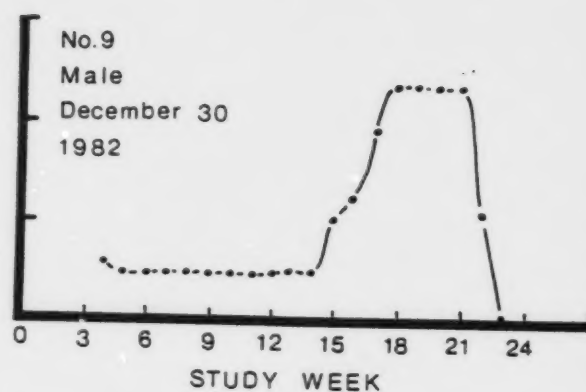
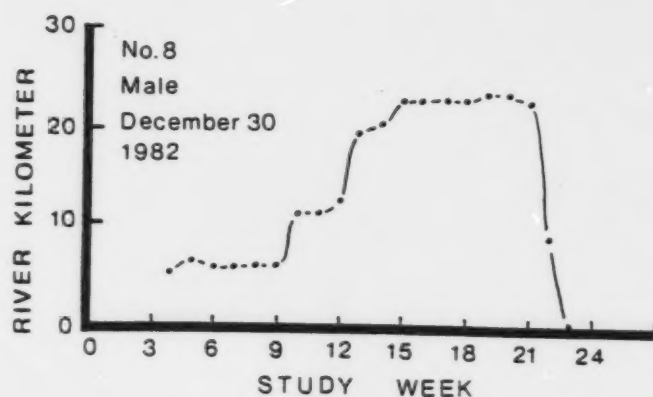
- radio tagged steelhead and number

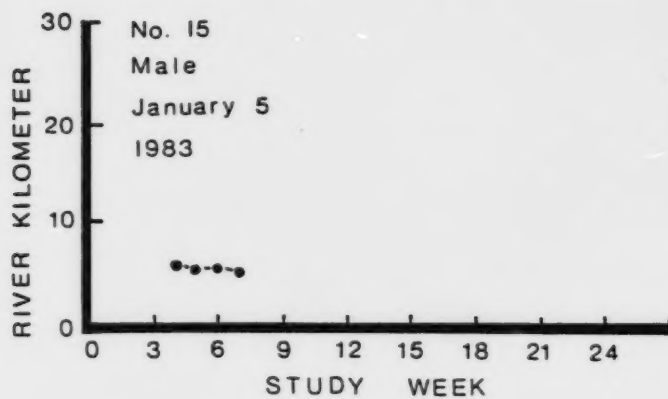


Appendix 2. Weekly locations of individual radio tagged steelhead by monthly tag group (December - April), Gold River, December 1, 1982 (week 1) through April 20, 1983 (week 25).

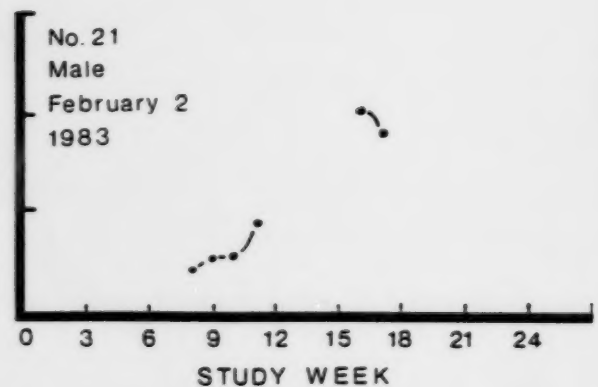
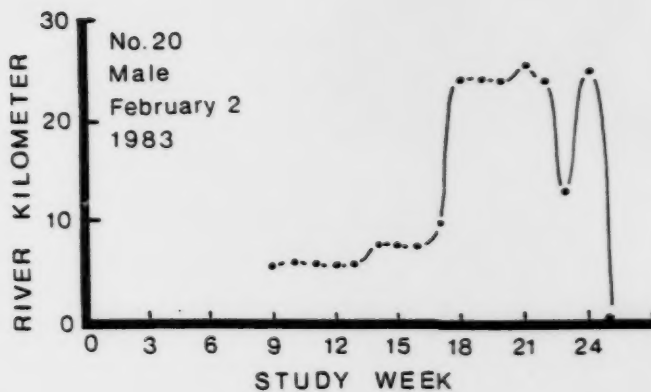
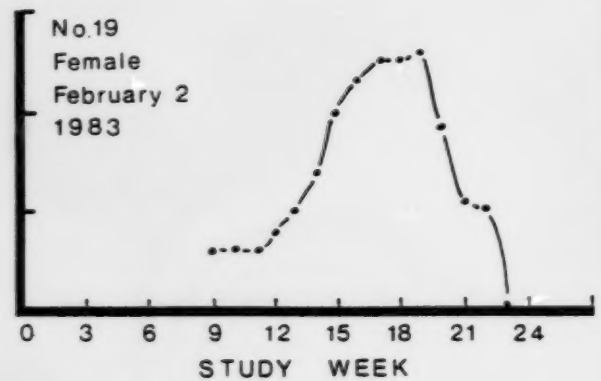
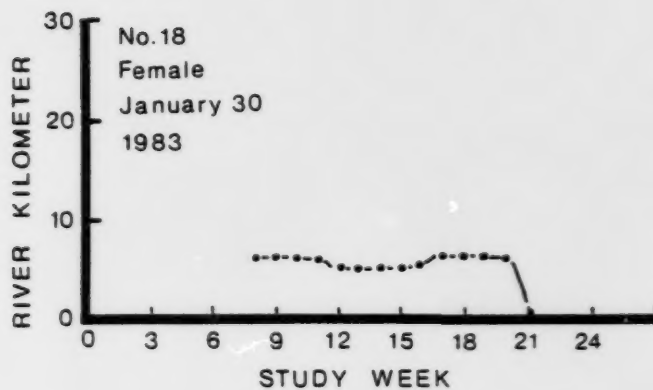
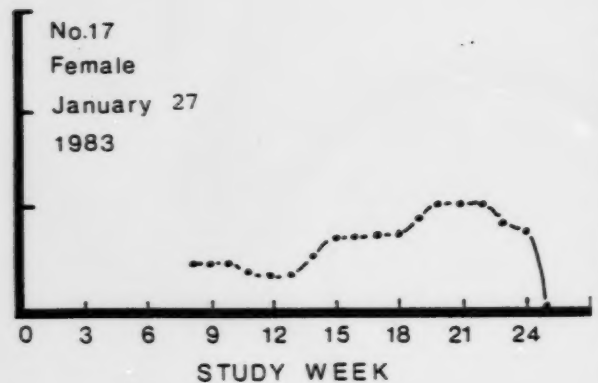
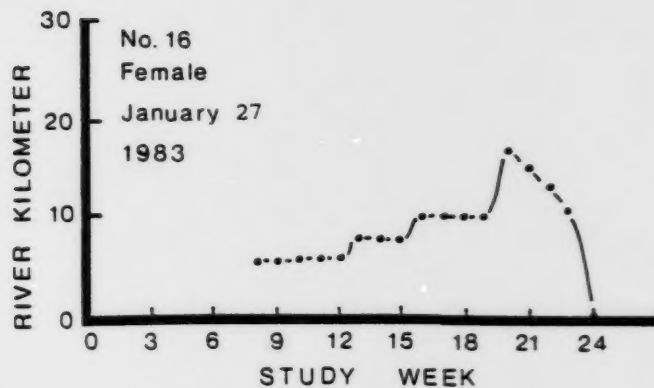


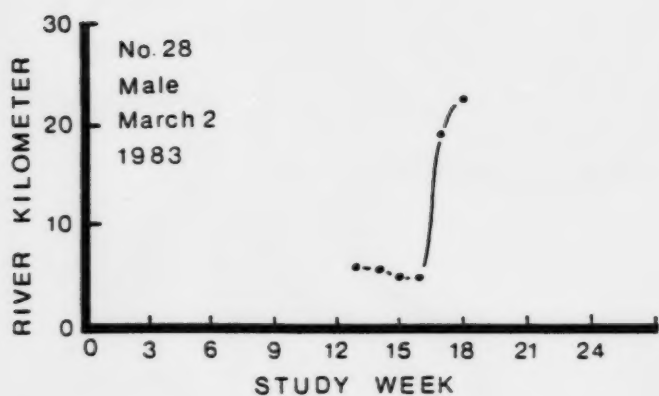
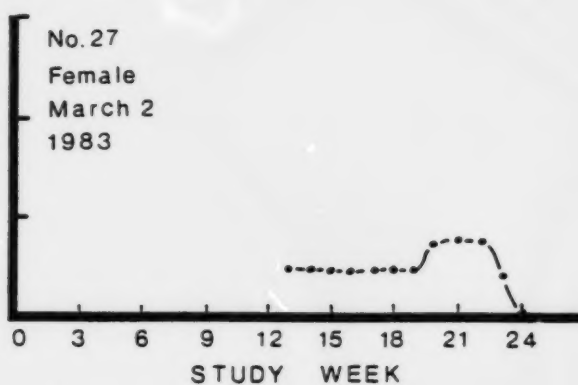
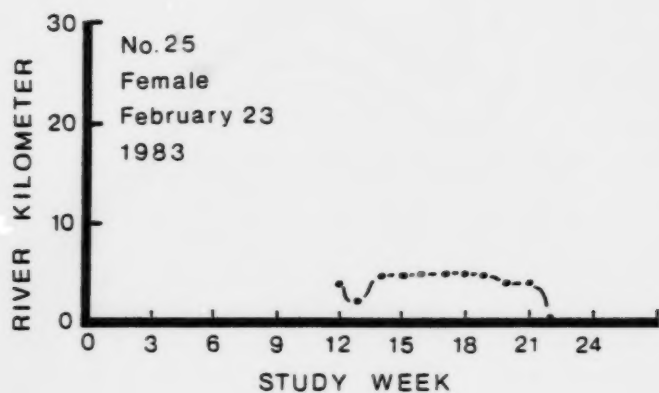
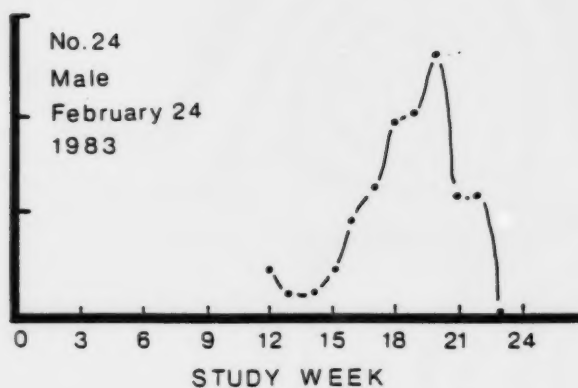
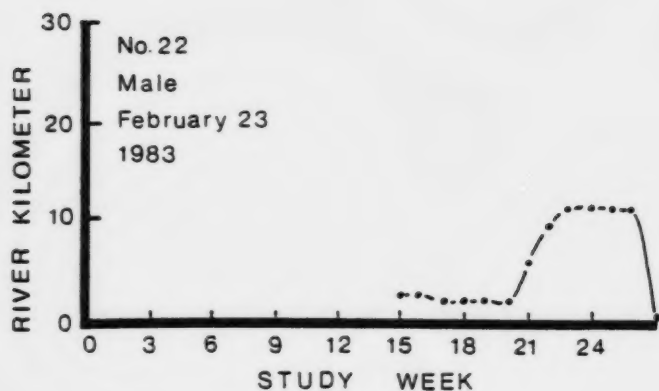
Appendix 2 (page 2)

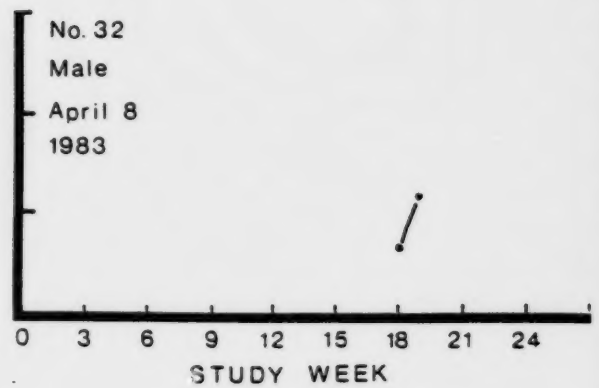
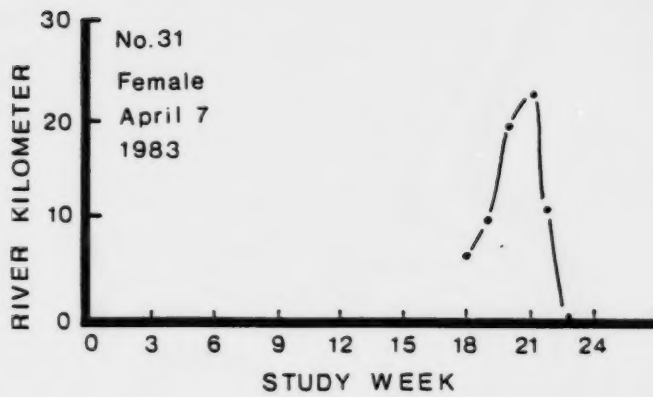
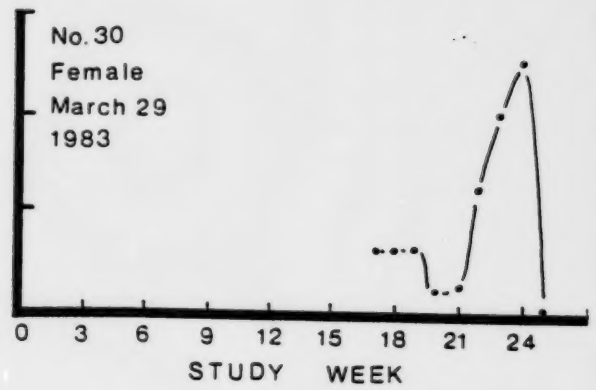
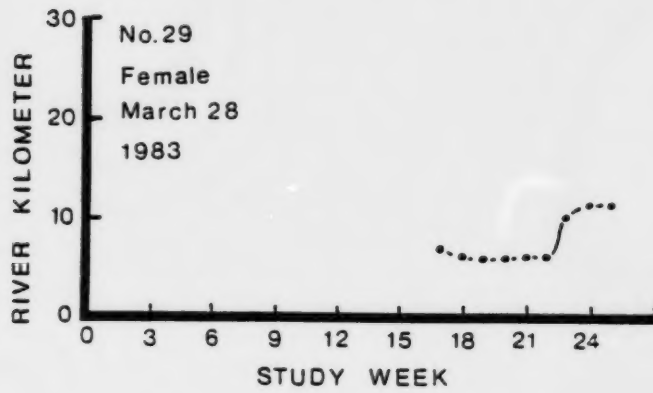




Appendix 2 (page 4)







List of previous Fisheries Technical Circulars

- 1985 67 Lirette, M.G., Hooton, R.S. and W.R. Olmsted. A Summary of Wild Steelhead Smolt Enumeration and Habitat Productivity Studies at Quinsam River, 1976-1984.
- 1985 68 Barrett, D.T. and G.T. Halsey. Vol. 1. Fisheries Resources and Fisheries Potential of Williston and its Tributary Streams.
- 1985 69 Bruce, P.G. and P.J. Starr. Fisheries Resources and Fisheries Potential of Williston Reservoir and its Tributary Streams.
- 69A Bruce, P.G. and P.J. Starr. Photo-Documentation of Williston Lake Tributaries for the 1975 Assessment of Fisheries Resource Potential.
- 1986 70 Dixon, B.M. Age, Growth and Migration of White Sturgeon in the Nechako and Upper Fraser Rivers of B.C.
- 1986 71 Billings, S.J. Steelhead Harvest Analysis, 1984-85.

List of previous Management Reports

- 1984 81 Parkinson, E.A. Identification of Steelhead Stocks in the Commercial Net Fishery of the Southern British Columbia Coast.
- 1984 82 Martin, A.D. and J.M. Bell. Effects of a 2.5 Year Closure of the Cutthroat Fishery on the Upper St. Mary River: Management Implications of Implementing an Alternate Year Closure on East Kootenay Trout Streams.
- 1984 83 Parkinson, E., R.J. Behnke and W. Pollard. A morphological and electrophoretic comparison of rainbow trout (Salmo gairdneri) Above and Below Barriers on Five Streams on Vancouver Island, B.C.
- 1985 84 A Questionnaire Survey of Vancouver Island Steelhead Anglers' Opinions and Preferences on Management Issues.
- 1985 85 Big Qualicum River Steelhead Fishery Investigations, 1976 to 1981.